Developing Cost-Effective Solar Resources with Electricity System Benefits

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George Simons
PIER Renewables

California Energy Commission

Approach

- Builds from earlier Solar Resources white paper
  - Considers only CSP and flat plate PV technologies
- Four steps
  - Develop performance & cost projections out to 2017
  - Bring in power flow analyses for "hot spots"
  - Co-located solar resources with "hot spots" and obtain economic potential
  - Use GIS and power flows to assess system impacts

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Conclusions for CSP

- Based on cost and performance trends, California has over 150,000 MW of economically viable CSP potential if the minimum developable solar resource is 7 kWhr-/m^2-day. The economic CSP potential drops to approximately 4500 MW if the minimum developable solar resource is 8 kWhr-/m^2-day.
- CSP systems located in areas with high insolation and that employ thermal storage or natural gas hybridization could feasibly be cost-competitive in RPS solicitations based on MPR prices.
- By 2010, approximately 1100 MW of economic CSP systems could be located in close proximity to substations capable of accepting generation and which represent "hot spots" in the state's electricity system. CSP systems located in close proximity to these substations would not need to pay for significant new transmission lines to bring their power into the grid.
- Power flow analyses show that bringing in the 1100 MW of CSP generation at the selected substations by 2010 will result in an electricity system benefit of approximately 3400 MW or a system benefit ratio of over 3 to 1 for every MW of installed CSP generation.
- At an estimated installed cost of approximately $2500/kW, the capital investment of deploying 1100 MW of CSP generation by 2010 would be $2.75 billion.

Conclusions for PV

- Under business-as-usual conditions, LCOE values for grid connected residential PV systems are expected to be close to $0.20/kWhr by 2010 and fall below $0.10/kWhr by 2020. Similarly, LCOE values for grid connected commercial building PV systems are expected to be above $.020/kWhr by 2010 and above $0.15/kWhr by 2017.
- PV systems can be cost effective in CA on the basis of tiered rates, TOU rates or financing arrangements that are either longer term or capture non-energy benefits from grid connected PV systems. However, more near-term and widespread adoption of PV systems will likely rely on public incentives.
- Under the Million Solar Roofs Initiative, approximately 500 MW of PV systems could be deployed in California by 2010 and over 2000 MW by 2017.
- Power flow analyses show that locating 500 MW of grid connected PV systems in the highest housing growth areas of the state can provide over 1000 MW of electricity system benefits.

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Trough: Performance & Cost Trends

			SunLab Cases		
	Baseline:	EPRI			
	SEGS VI	Near Term	Trough 100	Trough 150	Trough 400
Parameter/Year	**1989**	**2004**	**2004**	**2010**	**2020**
Net Power (Mwe)	30	100	100	150	400
Solar Field Optical Efficiency	0.535	NA	0.567	0.598	0.602
Gross Thermal Input (MWt)	88	NA	294	408	1087
Capacity Factor (%)	22%	33%	54%	56%	56%
Annual Solar to Electric Efficiency (%)	10.6%	13.0%	14.2%	17.0%	17.2%
Direct Capital Costs:					
o Structures & Improvements ($/kWe)	84	NA	73	54	[illegible]
o Solar Collector System ($/kWe)	1,493	NA	2,497	1,512	[illegible]
o Thermal Storage System ($/kWe)	0	NA	958	383	[illegible]
o Steam Generator or HX ($/kWe)	143	NA	100	74	48
o EPGS ($/kWe)	527	NA	367	293	197
o BOP ($/kWe)	306	NA	213	171	115
Total Direct ($/kWe)	2,553	3,150	4,208	2,487	1,916
O&M ($/kWhr)	0.025	0.017	0.0228	0.0135	0.0097

$2500/kW

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Trough: Cost Model Inputs & Results

Trough LCOE runs (no EPRI)				
Case/	SEGS VI	Trough 100	Trough 150	Trough 400
Year	1989	2004	2010	2020
Net Capacity (MW)	30	100	150	400
Capital Costs ($/kW)	2553	4208	2487	1916
O&M ($/kWhr)	0.025	0.0228	0.0135	0.0097
Capacity Factor (%)	22	54	56	56
LCOE ($/kWhr) w/o PTC	**0.181**	**0.130**	**0.075**	**0.057**
LCOE ($/kWhr) w/ PTC	**0.179**	**0.128**	**0.073**	**0.055**
Trough LCOE runs (EPRI)				
Case/	SEGS VI	EPRI Near Term	Trough 1[illegible]	[illegible]
Year	1989	2004	2010	[illegible]
Net Capacity (MW)	30	100	150	[illegible]
Capital Costs ($/kW)	2553	3150	2487	[illegible]916
O&M ($/kWhr)	0.025	0.017	0.0135	0.0097
Capacity Factor (%)	22	33	56	56
LCOE ($/kWhr) w/o PTC	**0.181**	**0.145**	**0.075**	**0.057**
LCOE ($/kWhr) w/ PTC	**0.180**	**0.143**	**0.073**	**0.055**
Wholesale price ($/kWhr)	**0.03**	**0.032**	**0.043**	**0.07**
E3: Combined Cycle ($/kWhr)	NA	**0.0694**	**0.0742**	**0.0915**

$0.073/kWhr

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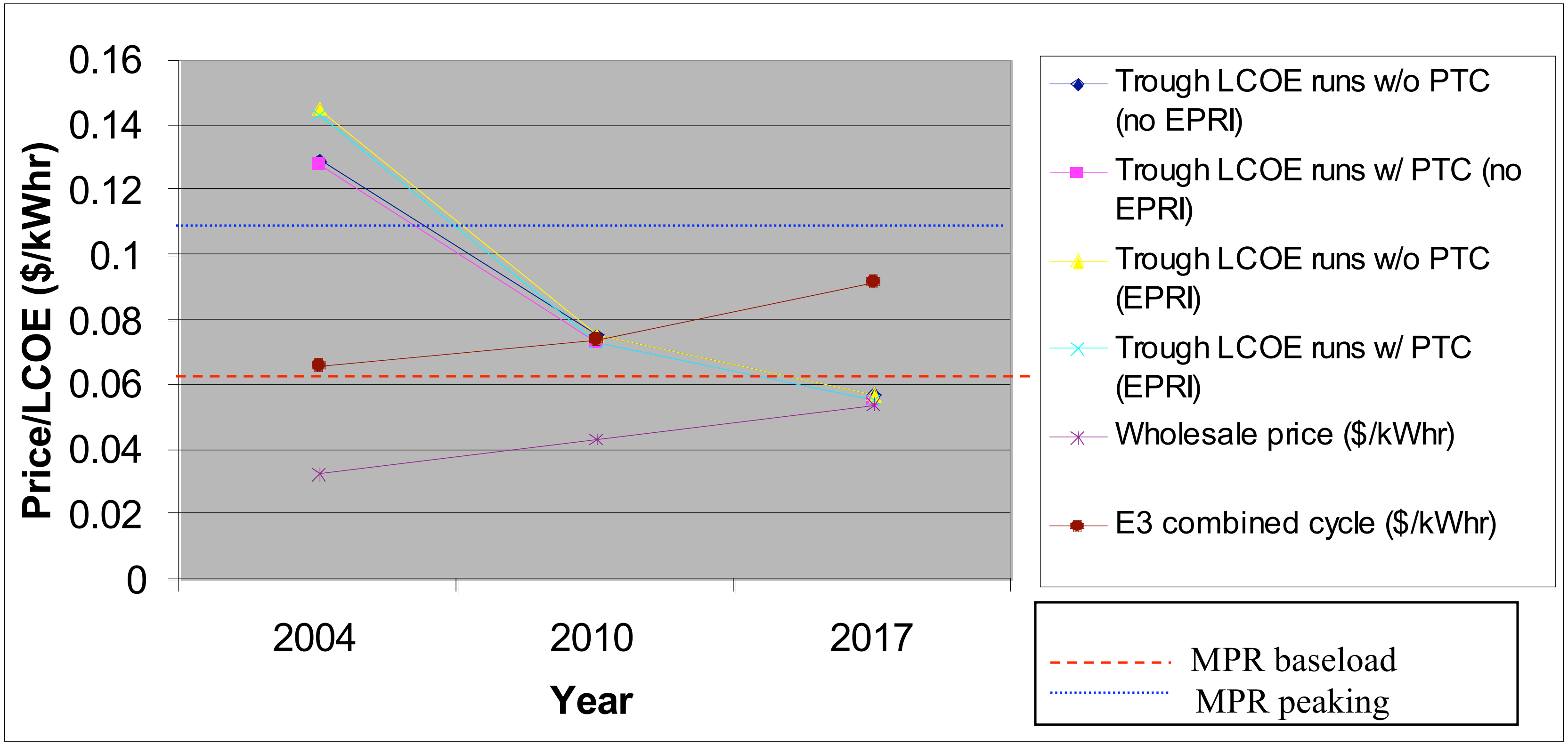
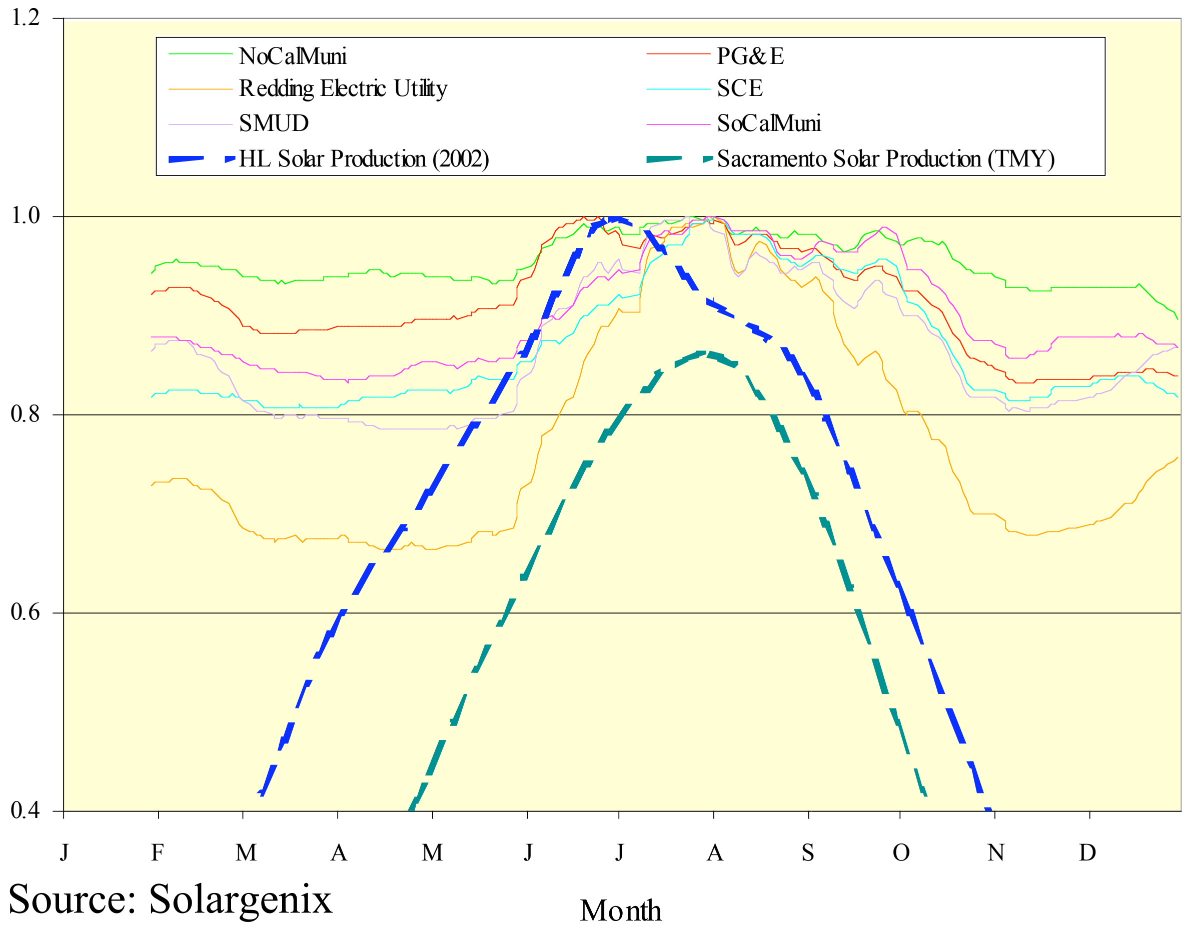
Trough: LCOE Values

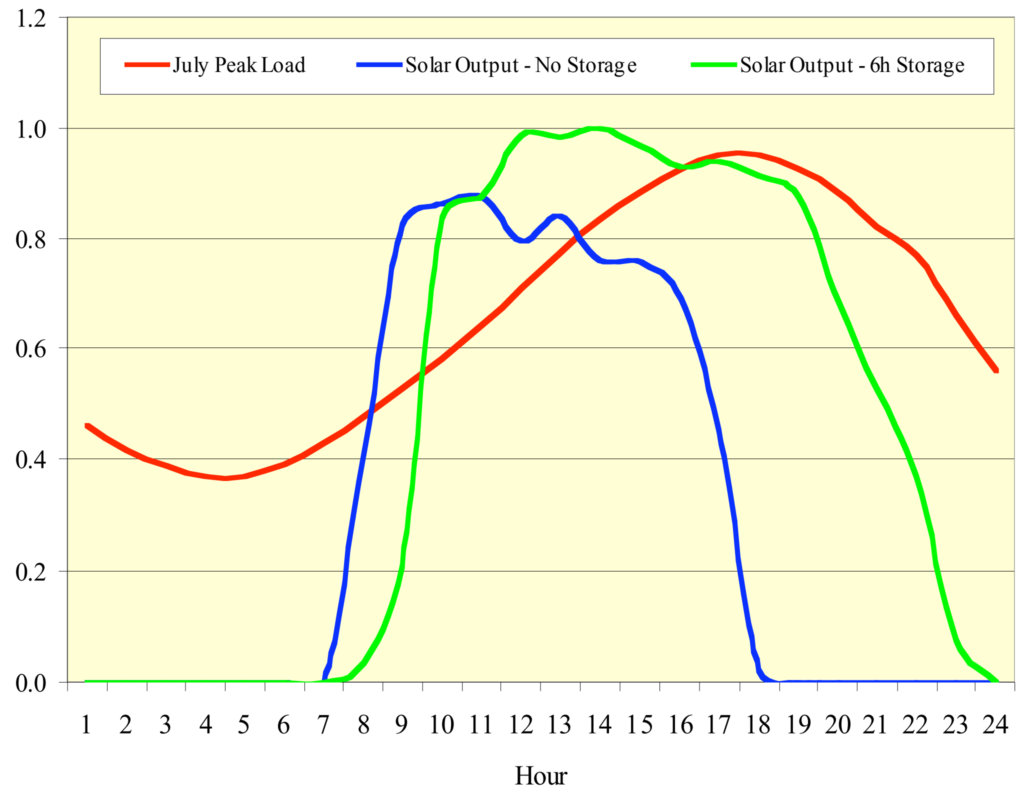


Comparison of Solar Production Against Load



Source: Solargenix

Impact of Storage on Matching Peak



Source: Solargenix

Tower: Performance Trends

		SunLab Cases				
	Baseline:	**Near Term**		**Mid-Term**		**Long-Term**
	Solar Two	**Solar Tres**	**Solar 50**	**Solar 100**	**Solar 200**	**Solar 220**
Parameter/Year	**1996**	**2004**	**2006**	**2008**	**2014**	**2018**
Power Cycle	Rankine	Rankine	Rankine	Rankine	Rankine	SuperCritical Rankine
Thermal Size (MWt)	42	120	380	700	1,400	1,400
Net Power (MWe)	10	13.65	50	100	200	220
Heliostat Size (m2)	39/95	95	95	148	148	148
Heliostat Design	glass/metal	glass/metal	glass/metal	glass/metal	glass/metal	advanced
No. of Heliostats	1,912	2,432	7,463	8,858	17,608	17,851
Solar Field (millions km2)	0.08	0.23	0.71	1.31	2.61	2.64
Collector Efficiency (%)	50.3	56	56.3	56	56.1	57
Annual Solar to Electric Efficiency (%)	7.9	13.7	16.1	16.6	16.9	18.1
Capacity Factor	19	78	76	73	74	73
Thermal Storage (hrs)	3	16	16	13	13	16

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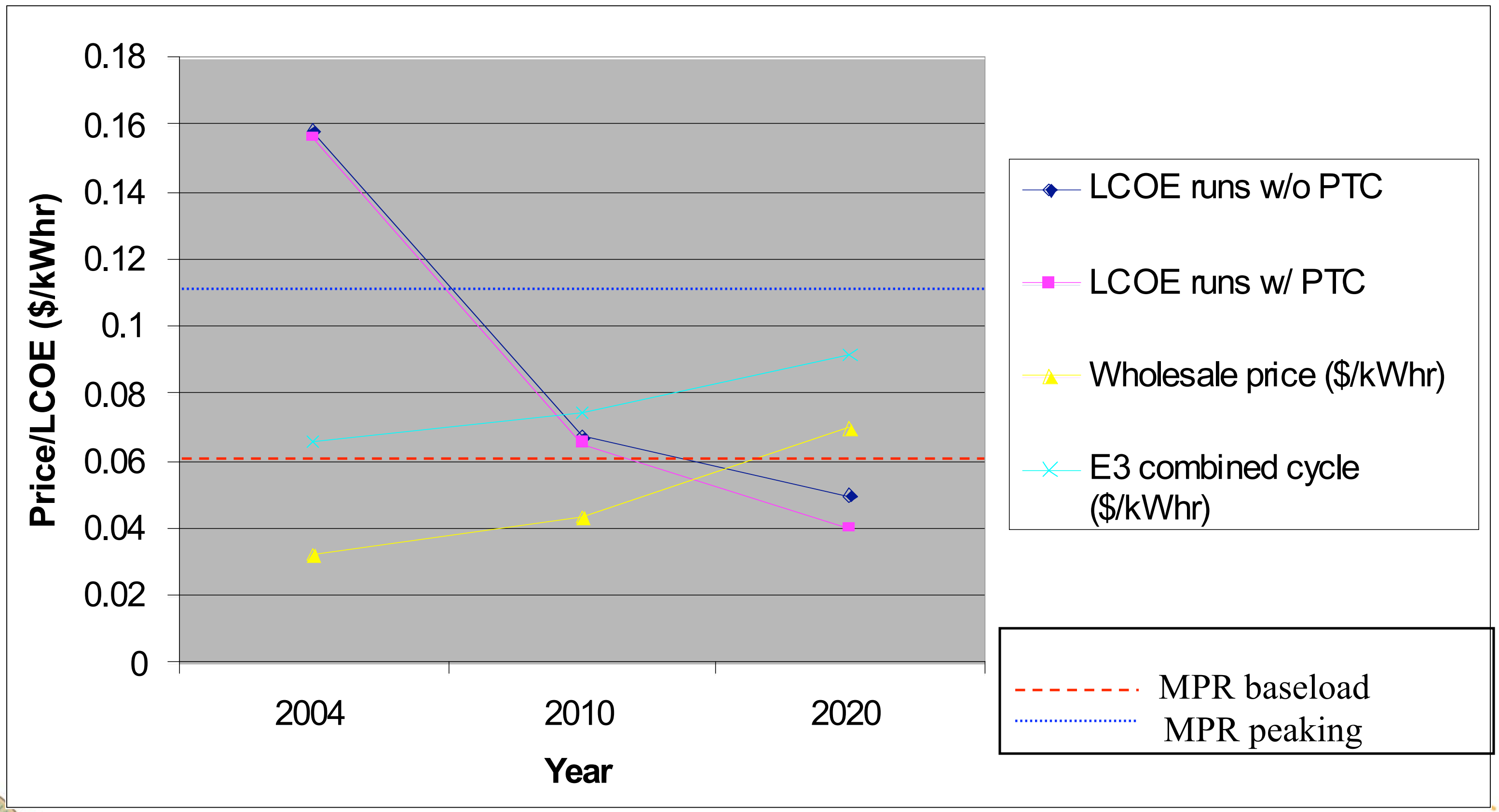
Tower: Cost Trends

		SunLab Cases				
	Baseline:	Near Term		Mid-Term		Long-Term
	Solar Two	Solar Tres	Solar 50	Solar 100	Solar 200	Solar 220
Parameter/Year	**1999**	**2004**	**2006**	**2008**	**2014**	**2018**
Net Power (MWe)	10	13.7	50	100	200	220
Thermal Size (MWt)	42	120	380	700	1400	1400
Heliostat Size (m2)	39/95	95	95	148	148	148
Heliostat Field (m2)	81,400	231,000	715,000	1,317,000	2,614,000	2,651,000
Annual Solar-to-Electric Efficiency (%)	7.6	13.7	15.7	16.5	16.8	17.8
Capacity Factor(%)	19	78	76	73	74	73
Capital Cost ($/kWe)	NA	7,180	4,160	3,160	2,700	2,340
O&M Cost ($/kWhr)	NA	0.033	NA	0.008	NA	0.006

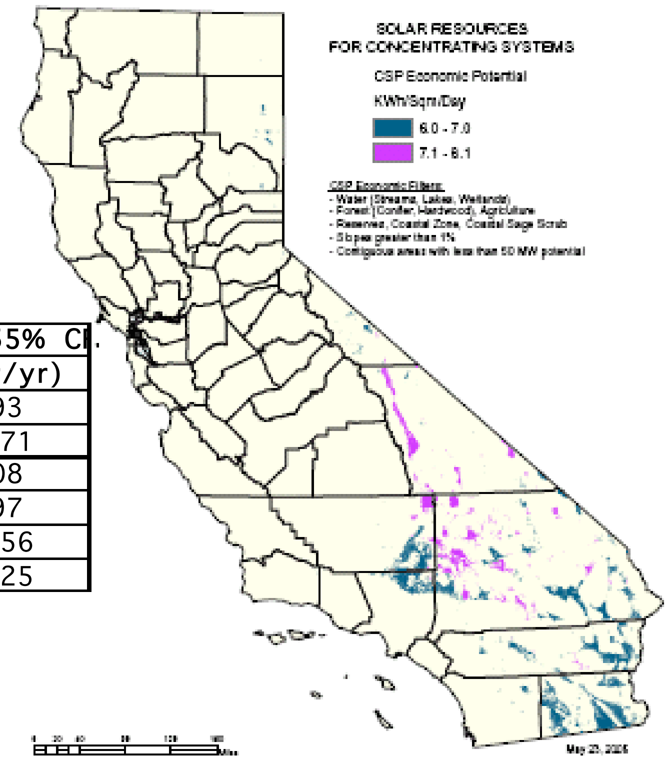
Tower: LCOE Values



CSP: Economic Potential

CSP economic potential is 150,000 MW at 7 kWhr/m^2-day, but shrinks to 4500 MW when the minimum solar resource is 8 kWhr/m^2-day

County	Suitable Area (m2)	Solar Capacity (MW)	Energy (25% CF) (GWhr/yr)	Energy (55% C (GWhr/yr)
INYO	112,500,000	5,561	12,179	26,793
KERN	929,920,000	45,967	100,669	221,471
LOS ANGELES	340,980,000	16,855	36,913	81,208
RIVERSIDE	101,180,000	5,001	10,953	24,097
SAN BERNARDINO	1,568,920,000	77,554	169,844	373,656
Totals:	3,053,500,000	150,939	330,557	727,225



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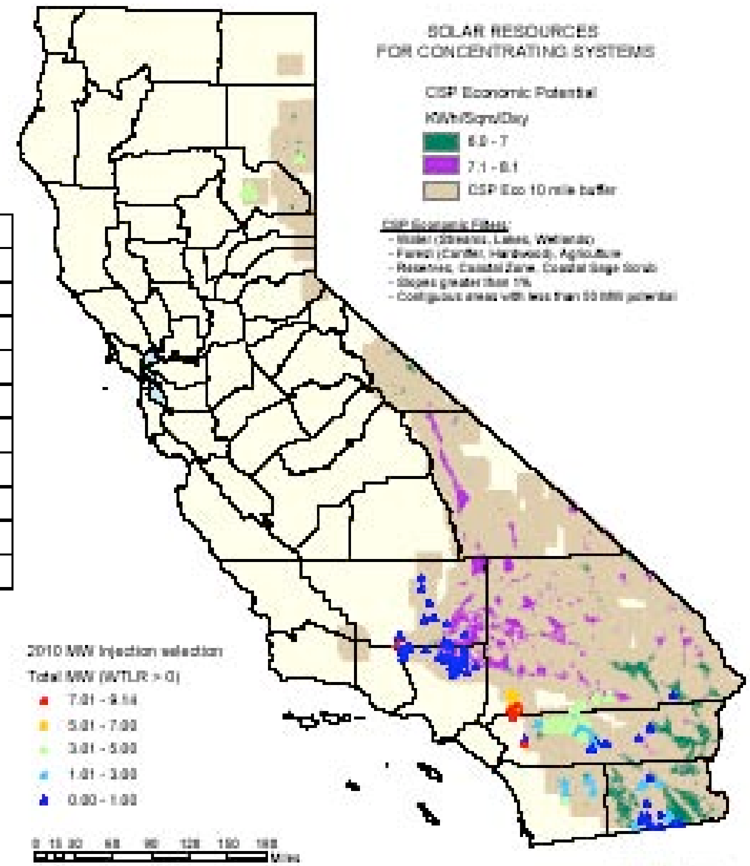
CSP: Economic Potential with WTLR

Economic CSP potential that intersects WTLR is ~ 1100 MW

County	DNI (kWhr/m2-day)	CSP Potential Intersecting WTLR > 0 (MW)	Economic CSP Potential Intersecting WTLR > 0 (MW)
Riverside	> 7.0	599	599
San Bernardino	> 7.0	477	477
Imperial	< 7.0	66	0
San Diego	< 7.0	35	0
Plumas	< 7.0	24	0
Totals:	NA	1201	1076



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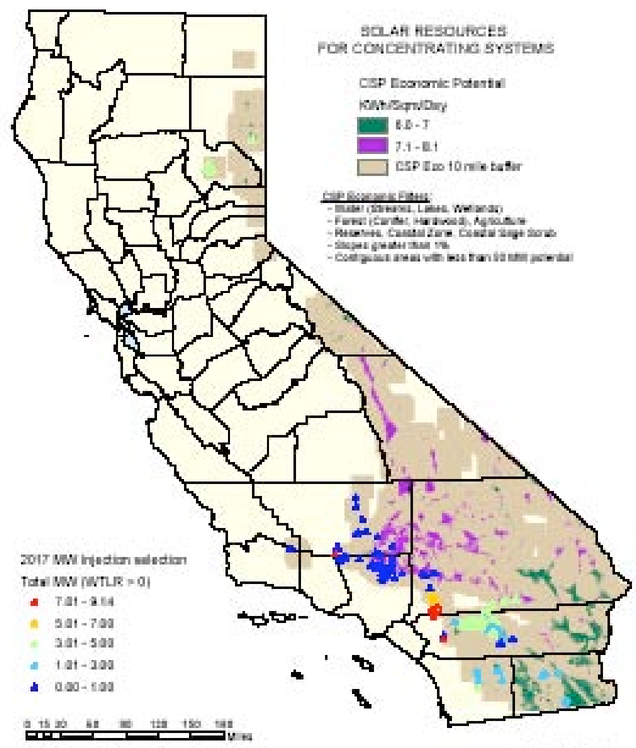
System Benefits with CSP Generation

Parameter/County	Riverside	San Bernardino
Contingencies	102	117
Violations	147	159
AMWCO	3,761 MW	3,986 MW
AMWCO Benefit	-1,794 MW	-1,569 MW
MW Installed	599 MW	447 MW
Impact Ratio	-2.99	-3.51



PV: Cost Trends

	2003	2008	2013
Parameter/Year	**Wafer**	**Wafer**	**Wafer**
System efficiency (%)	12	14.5	16.5
Residential (3 kWp)			
- Installed Price ($/kWac)	9,000	7,000	5,000
- O&M ($/kWp-yr)	15	13	10
Commercial (250 kWp)			
- Installed Price ($/kWac)	6,500	5,000	4,000
- O&M ($/kWp-yr)	13	11	9

Navigant Trends

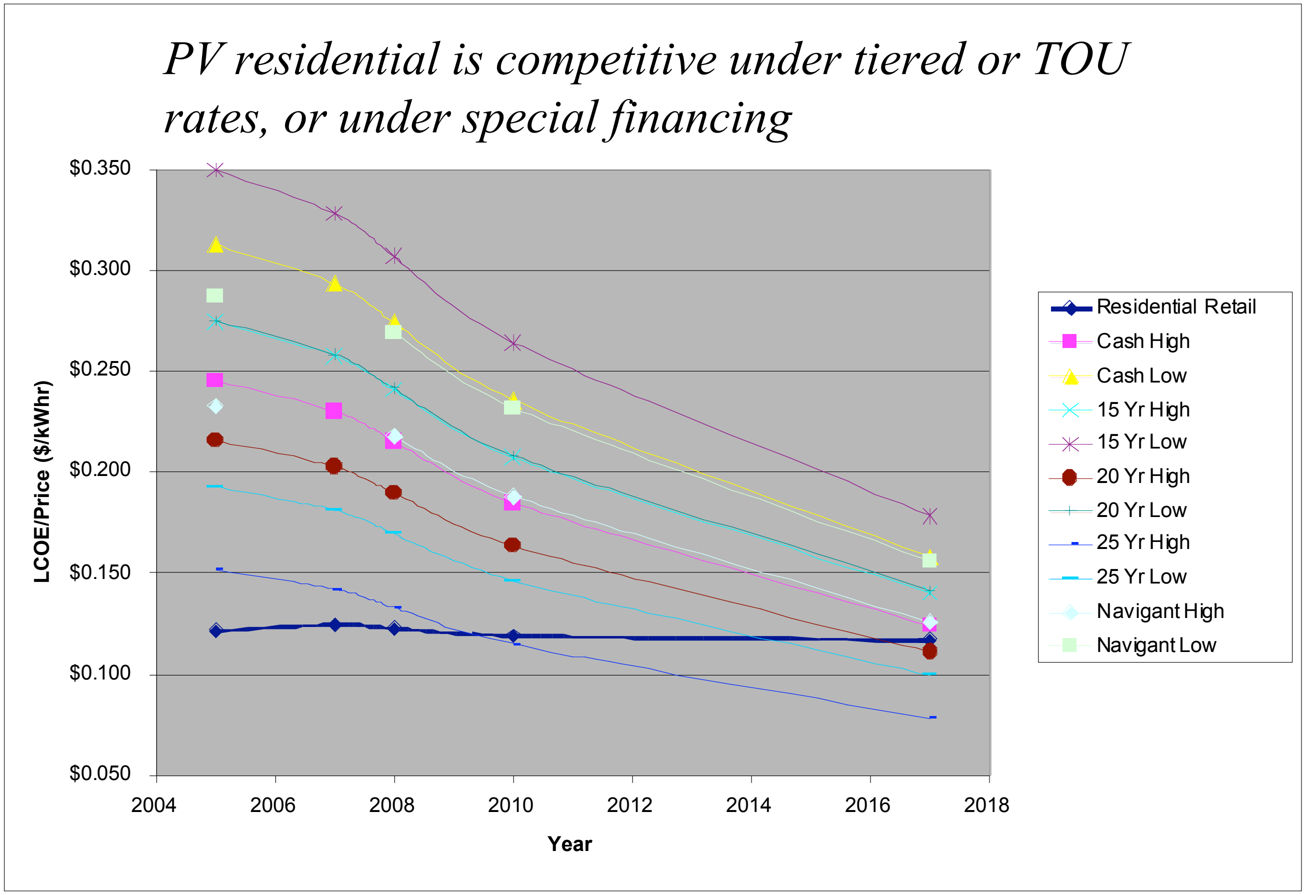
System Element	Units	2003	2007	2020
Design	$\$/W_{ac}$	0.25	0.15	0.10
Module Price	$\$/W_{p,dc}$	4.80	2.50	1.00–1.50
Direct cost/power	$\$/W_{p,dc}$	3.00	1.65	0.33–0.50
Conversion efficiency	%	14	15	15–20
Direct cost/area	$\$/m^2$	420	250	50–100
Inverter Price	$\$/W_{ac}$	1.10	0.50	0.30
DC-AC conversion efficiency	%	94	96	97
Replacement	Years	5	10	20
Other BOS	$\$/W_{ac}$	0.85	0.60	0.40
Installation	$\$/W_{ac}$	2.50	1.50	0.50
INSTALLED SYSTEM PRICE	$\$/W_{ac}$	6.20–9.50*	5.20	2.30–2.80
System Efficiency	%	11.5	14	16
Lifetime	Years	20	20	30
Degradation	%/Yr	1–2	1-2	1
O&M cost	$\$/kWh_{ac}$	0.08	0.02	0.005
LEVELIZED ENERGY COST	$\$/kWh_{ac}$	0.25–0.40*	0.22	0.8–0.10

Considerations:
LEC is cost to consumer.
2003 numbers taken from example of Figure 4.1.1-3.
LEC is dependent on solar resource (2000 $kWh/m^2/yr$ assumed here).
2003 data assume retrofit market; 2007 and 2020 are for new construction.
O&M primarily based on one inverter replacement every 5 years for 2003 figures; every 10 years for 2010 and 2020 figures.
*The ranges reflect the variability in calculations including various incentives and financing assumptions. LECs have been reported previously for year 2000 with incentives included.

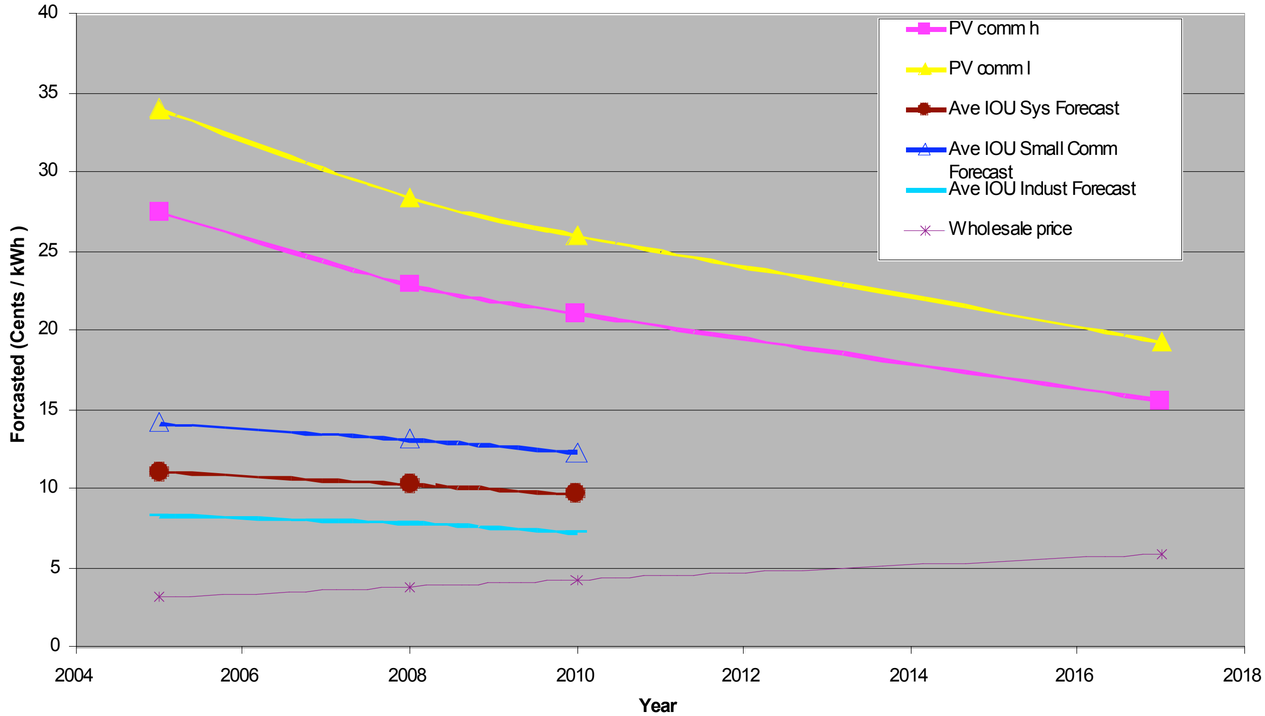
DOE Trends

Both Navigant and DOE cost trends show gradual decreases in PV costs under business as usual conditions

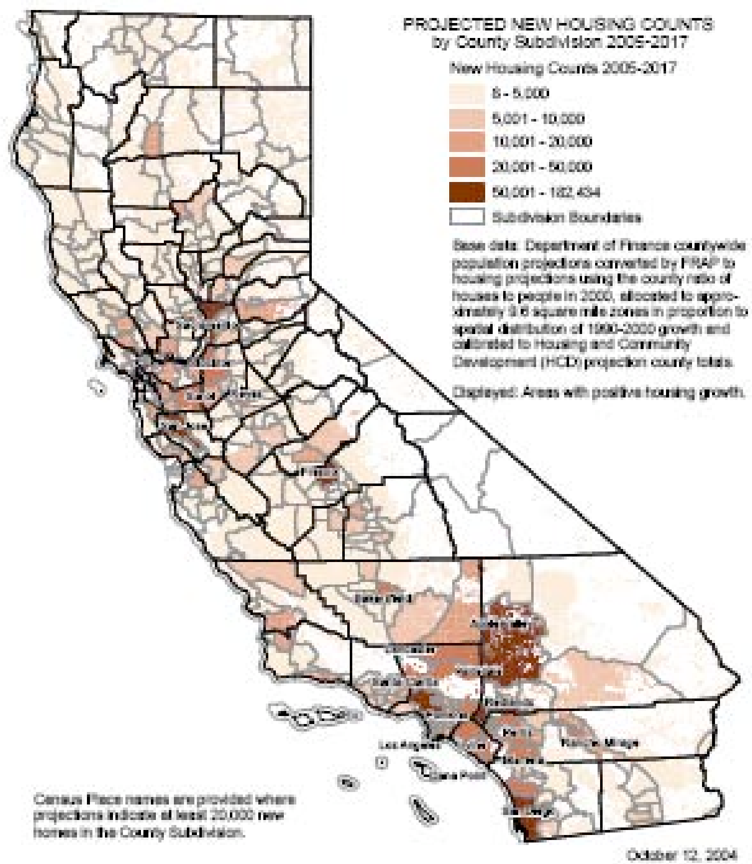
Residential PV: LCOE Values



Commercial PV: LCOE Values



New Housing 2005-2017



Locating PV at High Housing Growth Regions

Locating 500 MW of PV in high housing growth areas by 2010 provides an equivalent 1000 MW in net system (reliability)

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